

**BACKGROUND NOISE REDUCTION**

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**Abstract**

Interference by siren background-noise with speech transmitted from radio equipment (3) of an emergency-service vehicle, is reduced by apparatus (1) that subtracts (43) an estimate  $w_k$  of the correlated siren-noise component from the contaminated signal  $y_k$  supplied by the cab-microphone (2). The estimate  $w_k$  is computed by FIR (finite impulse response) filtering of a siren-reference signal  $x_k$  supplied by a unit (4) from one or more microphones located on or near the siren, or from the electric waveform driving the siren. The filter-coefficients  $w_k$  are adjusted according to an LMS (least mean square) adaptive algorithm that is applied to the correlated-noise component  $e_k$  of the feed-back noise-reduced signal, so as to bring about iterative cancellation with close frequency-tracking, of the siren noise.

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## Description

### Background-Noise Reduction

The present invention relates to background-noise reduction.

The invention is particularly concerned with the reduction of siren background-noise in voice communication from emergency-service vehicles.

Sirens used by police, ambulance, fire and other emergency-service vehicles are designed to give loud warning of the approaching vehicle over long distance.

Within the vehicle itself, the siren creates a high level of background noise that interferes with the intelligibility of voice messages communicated by radio from the vehicle. The siren background-noise within the vehicle is picked up by the communications microphone and can be so intense that it is necessary to turn the siren off to allow intelligible communication to take place.

The problem of interference with communication is troublesome and distracting for the crew of the vehicle, and turning the siren off to avoid it can seriously prejudice public safety. It is one of the objects of the present invention to provide methods and apparatus for overcoming the problem.

According to the present invention there is provided in one aspect a method, and in another aspect apparatus, for reducing siren background-noise in voice communication from an emergency-service vehicle, wherein an input representation of a signal that is derived from a microphone within the vehicle and contains a voice component together with an interfering component of siren background-noise, is submitted to LMS (least mean square) adaptive filtering using a siren-reference input such as to derive an output representation of a signal containing the voice component with the interfering component at least significantly reduced.

The input representation of the signal derived from the microphone may be combined with a representation of an estimate of the noise component to derive the output representation. In these circumstances, the representation of the estimate of the noise component may be derived by application of FIR (finite impulse response) filtering to the siren-reference input, the filter-coefficients being adjusted in accordance with values derived from application of the LMS adaptive algorithm to said output representation for reducing the noise component therein.

According to further aspects of the invention there are provided, respectively, a method and apparatus for reducing siren background-noise in voice communication from an emergency-service vehicle, wherein an input representation of a signal that is derived from a microphone within the vehicle and contains a voice component together with an interfering component of siren background-noise, is combined with a representation of an estimate of the noise component to derive an output representation of a signal containing the voice component with the interfering component at least significantly reduced, said representation of the estimate of the noise component being derived by application of FIR (finite impulse response) filtering to a siren-reference input, the filter-coefficients being adjusted in accordance with values derived from application of an LMS (least mean square) adaptive algorithm to said output representation.

The siren-reference input in the method and apparatus of the invention may be derived from a microphone located at or near the siren, or from an electric waveform used to drive the siren.

A method and apparatus for the reduction of siren background-noise in voice communication from an emergency-service vehicle, according to the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block schematic representation of the noise-reduction apparatus according to the invention; Figure 2 is a block schematic representation illustrating in terms of hardware, digital signal processing that is carried out within the noise-reduction apparatus of

Figure 1;

Figure 3 is a block schematic representation illustrative of the nature and functioning of a filter that is involved in the digital signal processing carried out within the noise-reduction apparatus of Figure 1; and

Figure 4 is a flowchart for the digital signal processing carried out within the noise-reduction apparatus of Figure 1.

Referring to Figure 1, the noise-reduction apparatus 1 is connected within the emergency-service vehicle to receive the output signal of a microphone 2 within the vehiclecab. The microphone 2, which is used for voice communication with a central-control station via two-way radio equipment 3 of the vehicle, inevitably picks up background noise from within the cab and combines this as a contaminating component with the required voice component. When the vehicle siren (not shown) is being operated, the noise component becomes so great that without the use of the equipment 1 intermediate the microphone 2 and the radio equipment 3, intelligibility of voice messages from the vehicle would be significantly impaired or lost altogether.

The apparatus 1 operates to derive from the noise-contaminated signal supplied by the microphone 2 an output signal in which the aperiodic voice component is retained and the periodic siren component is suppressed (to a substantial extent or altogether). This output signal is supplied to the equipment 3 for radio transmission so that voice messages given during operation of the siren are intelligible to the central-control station. Operation of the apparatus 1 to derive the output signal involves use of a reference signal which is representative of the output waveform of the siren and which is correlated to the noise component of the microphone signal. The correlated reference signal in this case is supplied from a unit 4, details of which are described later.

The microphone and reference signals are supplied within the apparatus 1 to respective filter-amplifiers 10 and 11 as a preliminary to analogue-digital conversion within individual converters 12 and 13. The digital signals from the converters 12 and 13 are supplied to a data processor 14 which carries out an adaptive-filtering program to suppress the siren-noise component of the signal from the converter 12. The resultant, output digital signal from the processor 14 is converted to analogue form in a converter 15, and after conditioning in a filter-amplifier 16 is supplied to the radio equipment 3 for transmission.

The digital signal processing of the microphone and reference signals carried out within the processor 14 implements a two-part adaptive filtering technique. The two parts of this technique, comprising digital filtering with adjustable coefficients and utilisation of an adaptive algorithm to adjust the coefficients, are illustrated schematically in terms of hardware in Figure 2 to which reference will now be made.

Referring to Figure 2, the digital signal derived from the microphone 2 and supplied to the processor 14 from the converter 12, is combined in an adder 20 with a digital signal that is derived by an FIR (finite impulse response) filter 21 from the digital reference signal supplied by the converter 13. The output of the adder 20 is representative of the difference between the two signals and is supplied to the converter 15 to provide the output of the processor 14. The output of the adder 20 is also fed back to adjust the filter-coefficients of the filter 21 in a manner to reduce the siren-noise component while at the same time tracking frequency variations of the siren.

The feed back to the filter 21 is effected via a unit 22 that operates in accordance with an LMS (least mean square) adaptive algorithm. The algorithm is utilised to adjust the filter-coefficients of the filter 21 to reduce significantly the siren-noise component in the output of the adder 20. In this respect, the filter 21 has an effective structure as illustrated in Figure 3 where the digital reference signal supplied by the converter 13 is identified as  $x_k$  and is submitted to successive time delays  $z^{-1}$  throughout (in this example) one hundred and nine stages 30 ( $N = 110$ ). The reference signal and the one hundred and nine progressively-delayed versions of it derived from the stages 30, are weighted according to individual filter-coefficients  $w_k$  and then added together in a summation stage 31. The result of the addition is supplied as an estimate  $n_k$  of the actual noise component

$n_k$  of the contaminated microphone signal  $y_k$  supplied by the converter 12.

By subtracting (in the adder 20) the estimate  $n_k$  of the noise component  $n_k$  from the contaminated signal  $y_k$ , an estimate  $s_k$  of the desired, noise-free signal  $S_k$  is obtained. This estimate  $s_k$  is used as the output signal of the processor 14 and is also fed back as an error signal  $e_k$  of the correlated noise component to adjust the filter coefficients  $w_k$  in the filtering process. The adjustment is made according to the LMS algorithm to tend to reduce the actual noise component  $n_k$  in the output signal  $s_k$  iteratively towards zero.

The adaptive-filtering process as a whole is carried out in the processor 14 as illustrated by the flowchart of Figure 4. As shown by the flowchart, the coefficients  $w_{ki}$ , where  $i = 0, 1, \dots, N-1$ , are initially ( $k = 0$ ) set to zero in stage 40 at the start of the process. The process then proceeds repetitively through five successive stages 41 to 45 for each of the sampling instants  $k = 1, 2, \dots$ . In stage 41 the values  $x_k$  and  $y_k$  are read from the

converters 13 and 12 respectively, and are used in stage 42 to compute the filter output.

From this, in stage 43, the error estimate  $e_k$  is computed as:  $e_k = Y_k - \hat{y}_k$

The value of the computed error estimate  $e_k$  is then used in stage 45 to update the filter-coefficients according to:

$$W^{+1}(i) = W_k(i) + 2 \cdot \lambda \cdot k \cdot e_k$$

following computation in stage 44 of  $2y_k$ , where  $\lambda$  is a constant (for example, 0.01) that controls the LMS adaption rate and therefore the effectiveness of the apparatus 1 in tracking the instantaneous frequency variation of the siren, for suppression purposes.

The sampling rate for the digital filtering process does not need to be high, but there can be advantages in adopting a rate as high as 44.1KHz, in particular for minimising aliasing problems.

There are various forms of siren in use with emergency-service vehicles. A form that uses an air compressor to drive horns of different lengths, and known as the "Hi-Lo"

Air Horn", has the broadest spectrum of current sirens of, on average 40Hz to 4KHz, with the low and high tones at 450Hz and 480Hz respectively; the spectral purity is very poor and the frequencies generated depend upon barometric pressure, vehicle speed, siren age and temperature. For the air-drive form of siren, the siren-reference signal supplied to the filter-amplifier 11 of the apparatus 1 of Figure 1 can be derived from one or more microphones located at or near the siren. More specifically, where a "Hi-Lo Air Horn"siren is involved, the unit 4 may take the form of an amplifier driven from contact microphones that are located one within each of the two horns of the siren.

Other forms of siren known as "Hi-Lo", "Wall", "Yelp" and "Pulsar"utilise electronically-generated signals driving loudspeakers. With the "Hi-Lo" electronic siren, the low and high frequencies are 700Hz and 1000Hz respectively, and the spectrum extends to 8KHz with a repetition period of the order of 760ms.

The "Wall"siren provides a chirp output that sweeps up and down linearly in frequency between 600Hz and 1800Hz with a repetition period of approximately 5.5s, and the "Yelp"siren has similar characteristics to these but with a faster repetition period of approximately 470ms.

Where the siren is electronically-driven, the sirenreference signal can be derived most effectively from the siren-driving signal. In this case therefore, the unit 4 may take the form of a signal-attenuating circuit supplied from the signal output of the siren-signal generator.

Tests carried out using siren noise-reduction apparatus as described above in emergency-service vehicles have proved very satisfactory in overcoming the communications problem. Table I below shows examples of attenuation of siren noise that have been achieved with the various types of siren identified above.

Table I

#### Siren Type Attenuation (dB)

Air horn "Hi-Low" 24-34

Electronically generated "Hi-Lo" 30 ~ 38

Electronically generated "Wall" 24-34

Electronically generated "Yelp" 18-24

Electronically generated "Pulsar" 7-12

It may be found desirable in some circumstances to delay slightly the microphone signal relative to the sirenreference signal. This can be achieved simply by introducing delay into the filter-amplifier 10.

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**CLAIMS**

- Claims:**
1. A method for reducing siren background-noise in voice communication from an emergency-service vehicle, wherein an input representation of a signal that is derived from a microphone within the vehicle and contains a voice component together with an interfering component of siren background-noise, is submitted to LMS (least mean square) adaptive filtering using a siren-reference input such as to derive an output representation of a signal containing the voice component with the interfering component at least significantly reduced.
  2. A method according to Claim 1 wherein the input representation of the signal derived from the microphone is combined with a representation of an estimate of the noise component to derive the output representation.
  3. A method according to Claim 2 wherein the representation of the estimate of the noise component is derived by application of FIR (finite impulse response) filtering to the siren-reference input, the filter-coefficients being adjusted in accordance with values derived from application of the LMS adaptive algorithm to said output representation for reducing the noise component therein.
  4. A method for reducing siren background-noise in voice communication from an emergency-service vehicle, wherein an input representation of a signal that is derived from a microphone within the vehicle and contains a voice component together with an interfering component of siren background-noise, is combined with a representation of an estimate of the noise component to derive an output representation of a signal containing the voice component with the interfering component at least significantly reduced, said representation of the estimate of the noise component being derived by application of FIR (finite impulse response) filtering to a siren-reference input, the filter-coefficients being adjusted in accordance with values derived from application of an LMS (least mean square) adaptive algorithm to said output representation.
  5. A method according to any one of Claims 1 to 4 wherein the siren-reference input is derived from a microphone located at or near the siren.
  6. A method according to any one of Claims 1 to 4 wherein the siren-reference input is derived from an electric waveform used to drive the siren.
  7. Apparatus for reducing siren background-noise in voice communication from an emergency-service vehicle, wherein an input representation of a signal that is derived from a microphone within the vehicle and contains a voice component and an interfering component of siren background-noise, is submitted to LMS (least mean square) adaptive filtering using a siren-reference input such as to derive an output representation of a signal containing the voice component with the interfering component at least significantly reduced.
  8. Apparatus according to Claim 7 wherein the input representation of the signal derived from the microphone is combined with a representation of an estimate of the noise component to derive said output representation.
  9. Apparatus according to Claim 8 wherein the representation of the estimate of the noise component is derived by application of FIR (finite impulse response) filtering to the siren-reference input, the filter-coefficients being adjusted in accordance with values derived from application of the LMS adaptive algorithm to said output representation.
  10. Apparatus for reducing siren background-noise in voice communication from an emergency-service vehicle, wherein an input representation of a signal that is derived from a microphone within the vehicle and contains a voice component together with an interfering component of siren background-noise, is combined with a representation of an estimate of the noise component to derive an output representation of a signal containing the voice component with the interfering component at least significantly reduced, said representation of the estimate of the noise component being derived by application of FIR (finite impulse response) filtering to a siren-reference input, the filter-coefficients being adjusted in accordance with values derived from application of an LMS (least mean square) adaptive algorithm to said output representation.

11. Apparatus according to any one of Claims 7 to 10 wherein the siren-reference input is derived from a microphone located at or near the siren.

12. Apparatus according to any one of Claims 7 to 10 wherein the siren-reference input is derived from an electric waveform used to drive the siren.

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WO 00/55846

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1/3

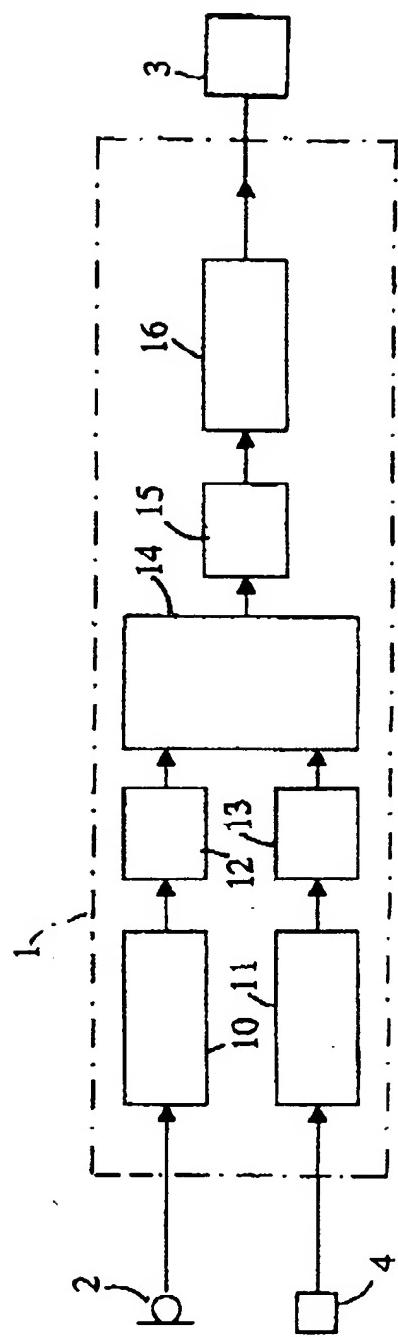


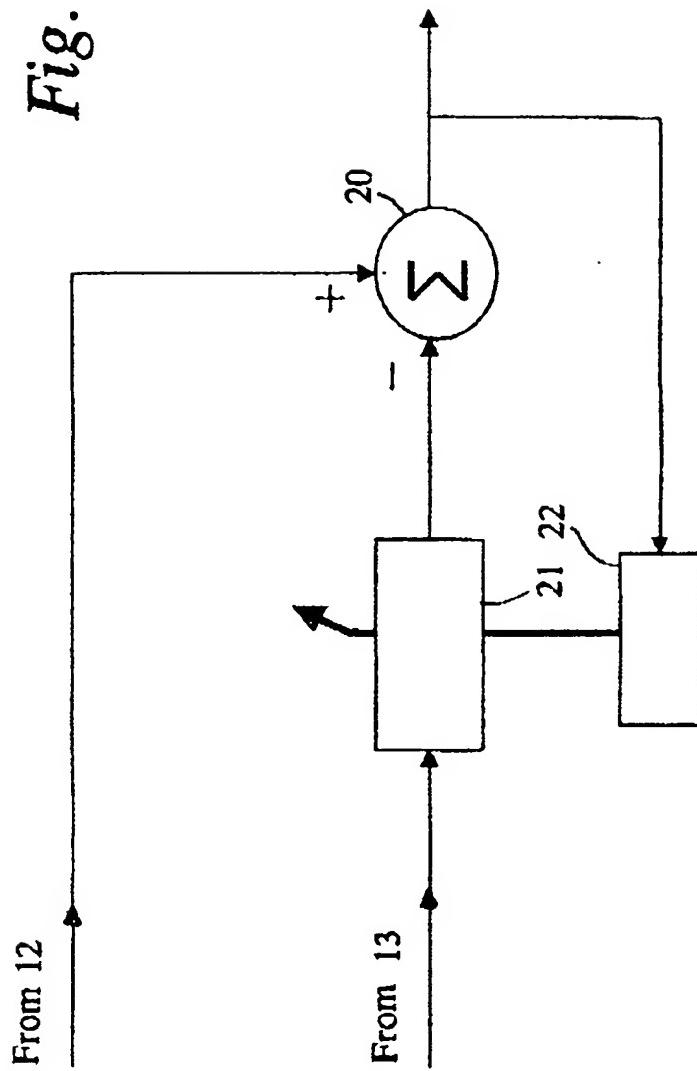
Fig. 1

WO 00/55846

PCT/GB00/00892

2/3

Fig. 2



WO 00/55846

PCT/GB00/00892

3/3

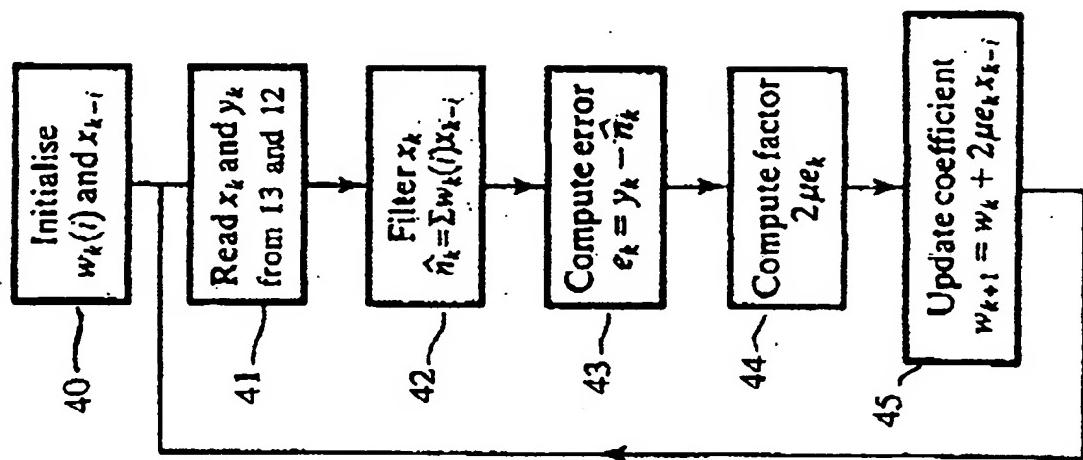


Fig. 4

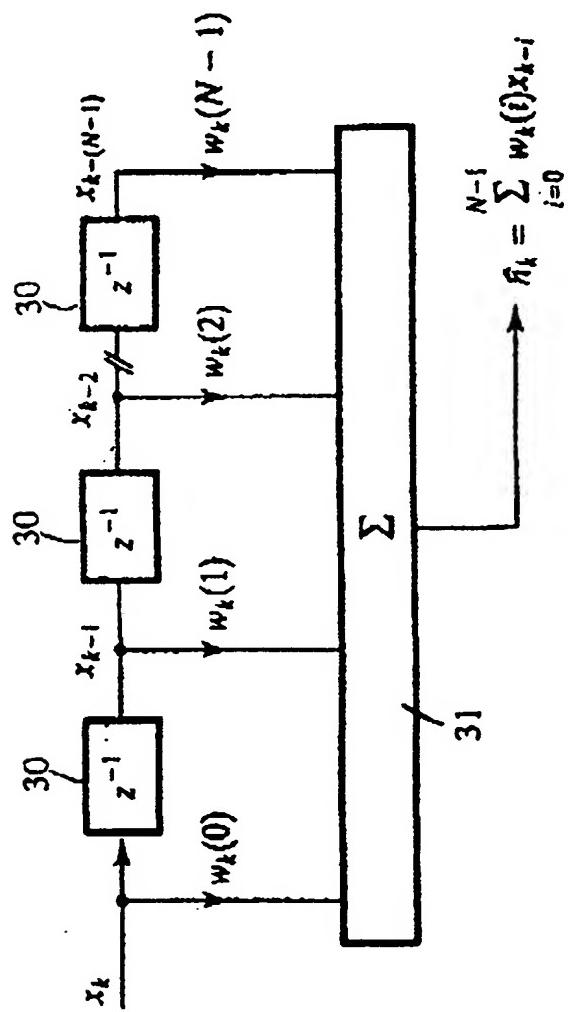


Fig. 3